

NUMERICAL MODELING OF BACKFILLING PROCESS AROUND MONOPILES

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This paper presents the results of a three-dimensional (3D) numerical modeling study on the backfilling process around monopiles. The numerical model utilized in the study is based on that given by Jacobsen (2011). It is composed of two main modules. The first module is the hydrodynamic model where the fluid flow conditions around the structure and near the bed are solved. The second module is the morphologic model where the sediment transport rates over the bed and around the structure are obtained and used in updating bed elevations around the structure. In the numerical model, the hydrodynamic computations are followed by morphologic computations, resulting in updated bed elevations and mesh structure, which are in turn used to update the hydrodynamics for the next time step. In the hydrodynamic model, Reynolds-Averaged Navier-Stokes (RANS) equations are solved with a $k-\omega$ turbulence closure. The morphologic model comprises five sub-modules, namely bed load, suspended load, sand slide, bed evolution and 3D mesh motion. The model is constructed in open-source CFD toolbox OpenFOAM^{®1}. The modules related to the bed load, the sand slide, the bed evolution are the same as those used in Roulund et al. (2005). The present model is applied to several scenarios of backfilling of a scour hole around a monopile by waves, with the initial scour hole generated either by steady current or by larger waves. The example illustrated in Figures 1 and 2 is the backfilling of a scour hole generated by a steady current over an initially flat bed. In the simulation, the median grain size is taken as 0.17 mm and the model pile diameter is taken as $D=0.04$ m. The dimensions of the computational domain are $20D$ (length) $\times$ $15D$ (width) $\times$ $2D$ (height). The initial bed profile (Fig. 1a) is achieved with a steady current in a scour simulation, in which the current velocity is $V=41$ cm/s, the friction velocity is $U_f=1.9$ cm/s, and the corresponding Shields parameter is $\theta=0.13$, larger than the critical value for the initiation of motion, $\theta_c=0.05$, implying that the scour is in the live-bed regime. The equilibrium scour depth obtained in the steady current simulation is $S/D=0.91$ (Figure 1a), where S is the scour depth in front of the pile. This value agrees well with the existing data, for the present water-depth-to-pile-diameter ratio $\delta/D=2$ in the simulation (Sumer and Fredsøe, 2002). In the backfilling simulation, the maximum value of the free-stream velocity of the wave-induced oscillatory flow in the test is $U_m=22.5$ cm/s and the wave period is $T=1.786$ s, with a Keulegan-Carpenter number of $KC=10$. The Shields parameter is $\theta=0.15$, implying that the backfilling is also in the live-bed regime. Figure 2 shows the time development of backfilling for 190 wave periods. The dashed line in Figure 2 represents the equilibrium scour

depth for the same Keulegan-Carpenter number, $KC=10$, obtained from Sumer et al.'s (1992) scour experiments. As seen, the depth of the scour hole of the backfilling process eventually approaches the same value as that experienced in the ordinary scour process for the same KC number, observed first by Sumer et al. (2013) for piles.

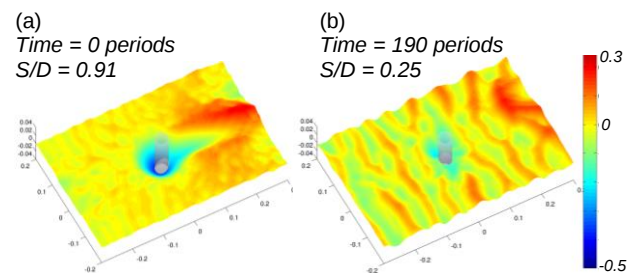


Figure 1 - (a): The equilibrium scour hole around the pile for steady current. (b): The backfilled scour hole after 190 wave periods ($KC=10$).

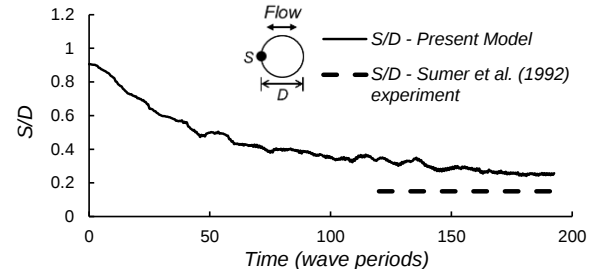


Figure 2 - The time development of scour depth during backfilling ($KC=10$).

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